Successful slope stabilization under severe conditions

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Abstract

Two examples of successful slope stabilization show the versatility and strength of micropiles, when stabilizing slipping slopes or refurbishing damages at different structures under severe climatic conditions and inaccessible areas all over the world. The following paper includes a short history of the two projects and shows the technical and overall challenge in two very different surroundings – high alpine in Europe and mountain area in India 200 km southeast of Mumbai.

Case 1 – Slope stabilization in high alpine surrounding

In 1990 a difficult foundation of a ropeway station was erected on a steep slope near St. Anton/Arlberg. Vertical column loads of more than 4500 kN, avalanche loads in horizontal direction of about 10 kPa and information of supposed creeping – although no survey proved this – were a big challenge. To get necessary information on soil test drillings were made to a depth of 15 m, which showed a subsoil layer of about 6 meters covering a weathered rock surface. Water could be found at the upon rock surface.

Based on these data design was performed and lead to the solution using micropiles as foundation I the 35° steep slope.

Within 3 weeks nearly 2300 m of micropiles GEWI 50 at single lengths of up to 15 m were drilled. Results of several pile testing led to a working load of 550 kN per pile. After finishing the projects survey proved that the structure was stable and no movements could be identified.

In late May 1999 following a winter with an immense amount of snow, heavy rain caused a slope slide at the bottom of the station, which left parts of the station building standing free on the micropile foundation. The damage was repaired by the use of additional micropiles and concrete foundation to close the gap and prevent further damage.

Permanent survey showed that the slope was creeping since then at a speed of approximately 30 mm per year. As movement of the structure was parallel to the ropeway axis this caused no technical problems.

In August 2005 flooding rain caused more damage as parts of the right hand side slope, where the station is situated, were torn away by the torrent passing down the valley.

Survey in October 2005 did not show any increase of creeping speed, but in October 2006 survey proved, that movement had dramatically increased to 300 mm horizontal and 180 mm vertical. The Austrian Ropeway authority closed the ropeway and asked for a stabilization project and suggestions to allow running the ropeway during winter 2006/2007. A permanent survey of the slope and level control of the station building was installed and reviewed daily. Due to low temperatures and lack of water in the ground, creeping velocity decreased during winter to 5 mm per week. Starting spring movements increased again to 10 mm/week.

Beginning of July 2007 - after snow was gone - stabilization works started. Due to inaccessible and steep terrain a solution using micropiles was chosen, in order to reach each installation point. Project consisted of two main items – securing bank line of the torrent “Steissbach” and stabilizing the slope by using micropile walls and drainage systems to extract water from the ground.

Drilling cores from time of erection of the station in 1990 showed rock surface at a depth of 5-7 m below surface as well as water on that level. Soil was a moraine – silty clay with stones up to 500 mm dia. – that due to slipping was loosely packed.

Besides the “micropile walls” – two of them with micropiles arranged in A-shape – and three more with micropiles in vertical direction or orthogonal to the natural fall – drainage of the slope was a main issue.

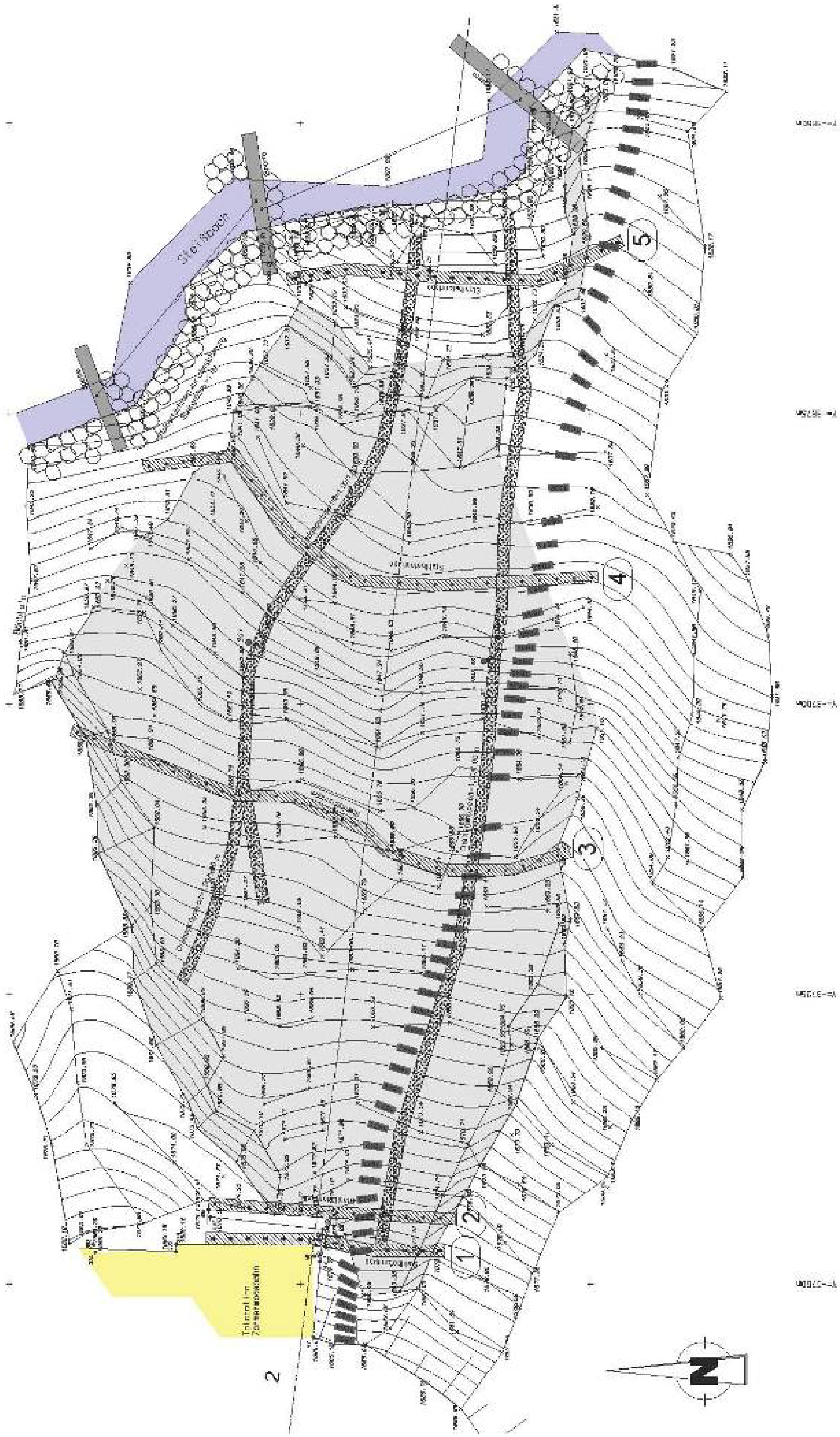
1 site view from top of station down to “Steissbach”

Starting with stability analysis soil parameters were varied till safety proved to be around 1,00. Based on that, stabilizing measures and drainage systems were induced to lift stability to at least 1,40. This led to the final solution using 5 micropile walls – GEWI 50 – head connected with a concrete slab, drainage system and gulleys to bring surface water down to the torrent including bank line and river bed stabilization.

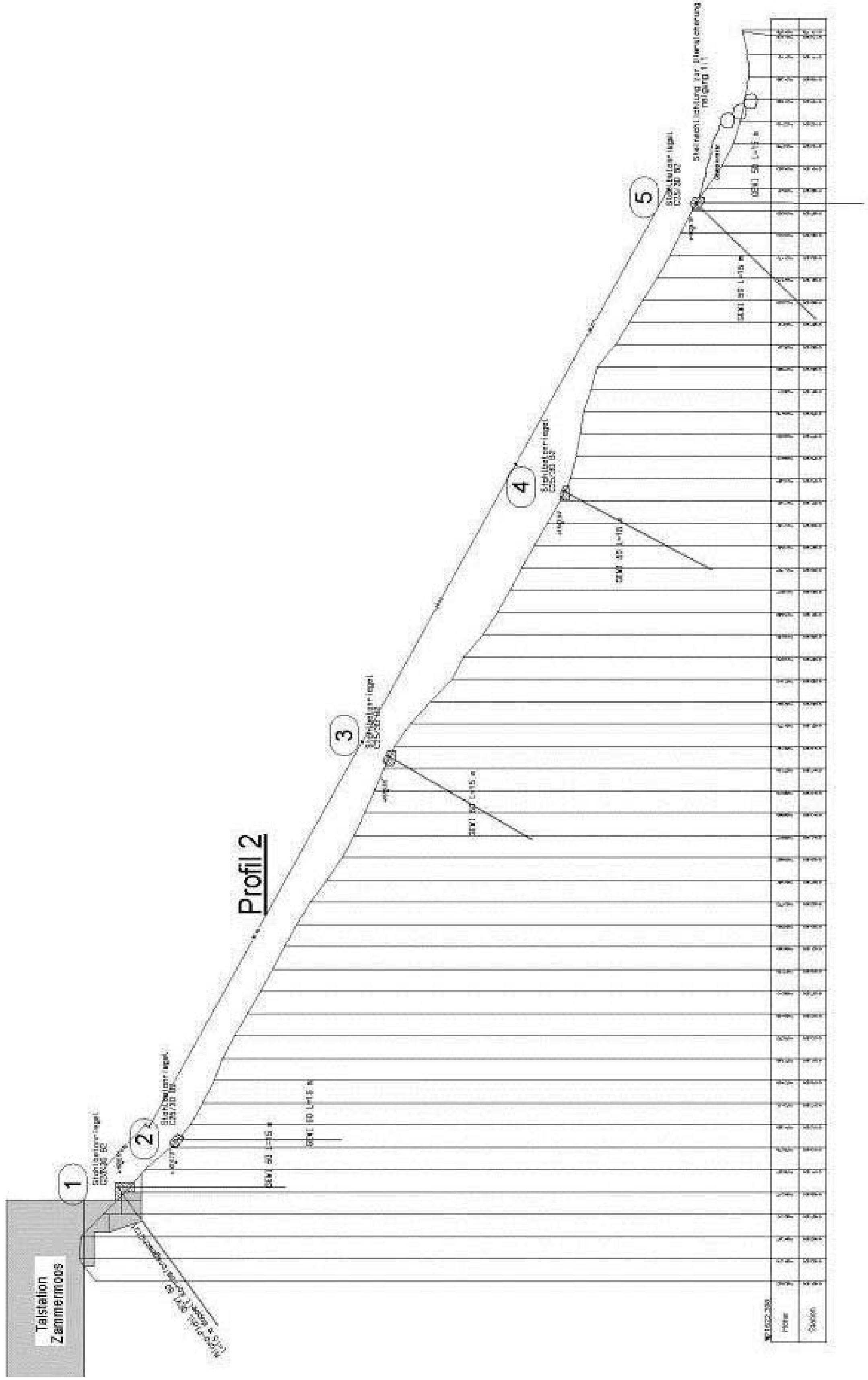
During negotiations of the tendering type of micropiles was changed to hollow bar MAI IBO R51N micropiles instead of GEWI. This decision was influenced mainly by short erection time considerations.

To obtain the same resistance of the system horizontal spacing of MAI IBO micropiles was reduced.

After site installation and preparing access for drilling equipment 5205 m of micropiles – single pile length 15 m - were drilled within a period of 2,5 months. Concrete slabs on top were finished by end of October 2007, when works had to be stopped due to early winter on site.

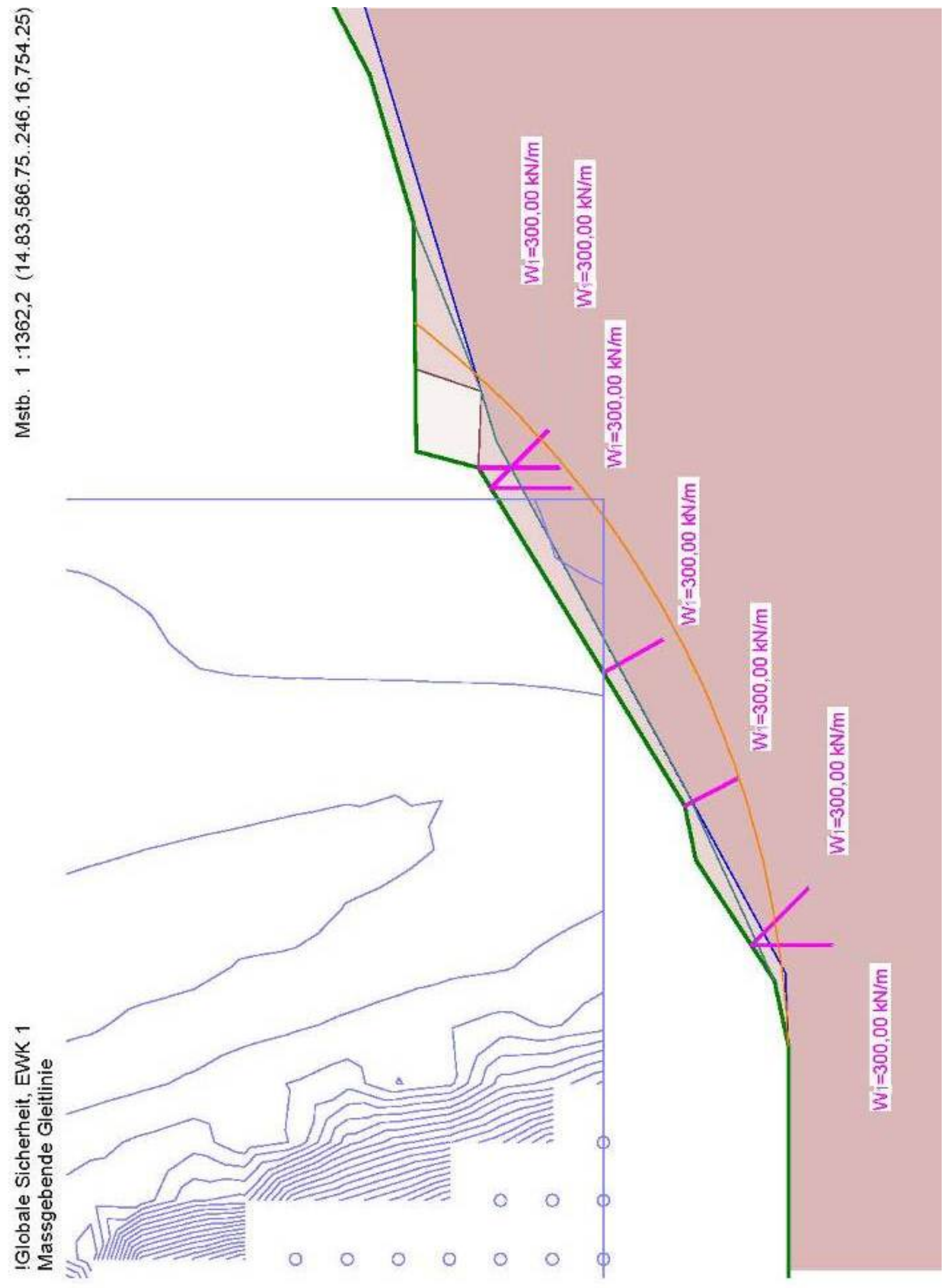


2 top view of site – 5 MP-walls, drainage and gulleys

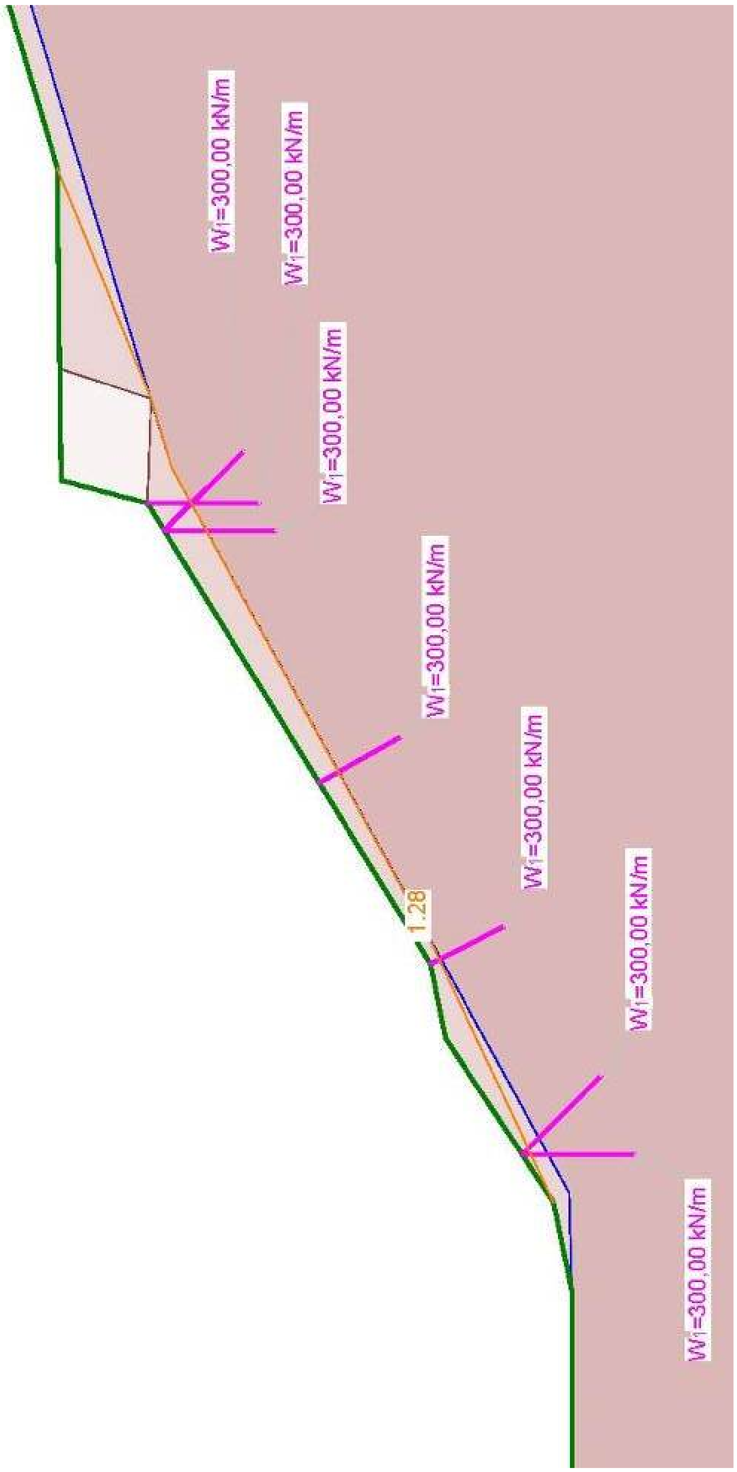


3 section of site

In order to support the station structure an A-system of micropiles was provided close to the foundation slab of the building. Micropile walls down the slope were seen as dowelling elements permitting head movement. At the bottom another A-system was installed in order to support overlying soil near torrent bank line.
Stability was analyzed with circular sliding areas per KREY and polygonal areas per JANBU.



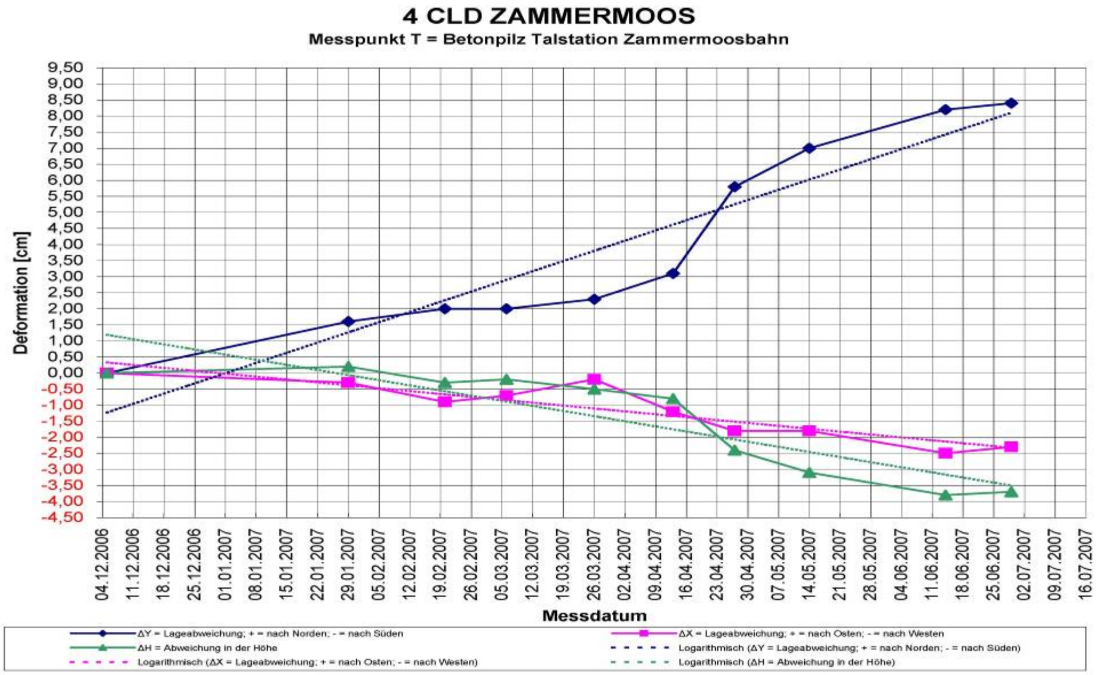
4 stability analysis KREY



5 stability analysis JANBU

Torrent bed was stabilized by installing 3 concrete barriers to prevent further riverbed erosion causing slipping of the bank.

During the whole building process, survey was continued and reviewed.



6 survey at beginning of stabilization work

After another snowy winter stabilization works, which proved to be successful, were finished and everything cleaned. On the right hand side of the station building a surface stabilization with a system of heavy duty wire mesh and nails was provided to prevent shallow slippage and erosion – compare picture no 7.

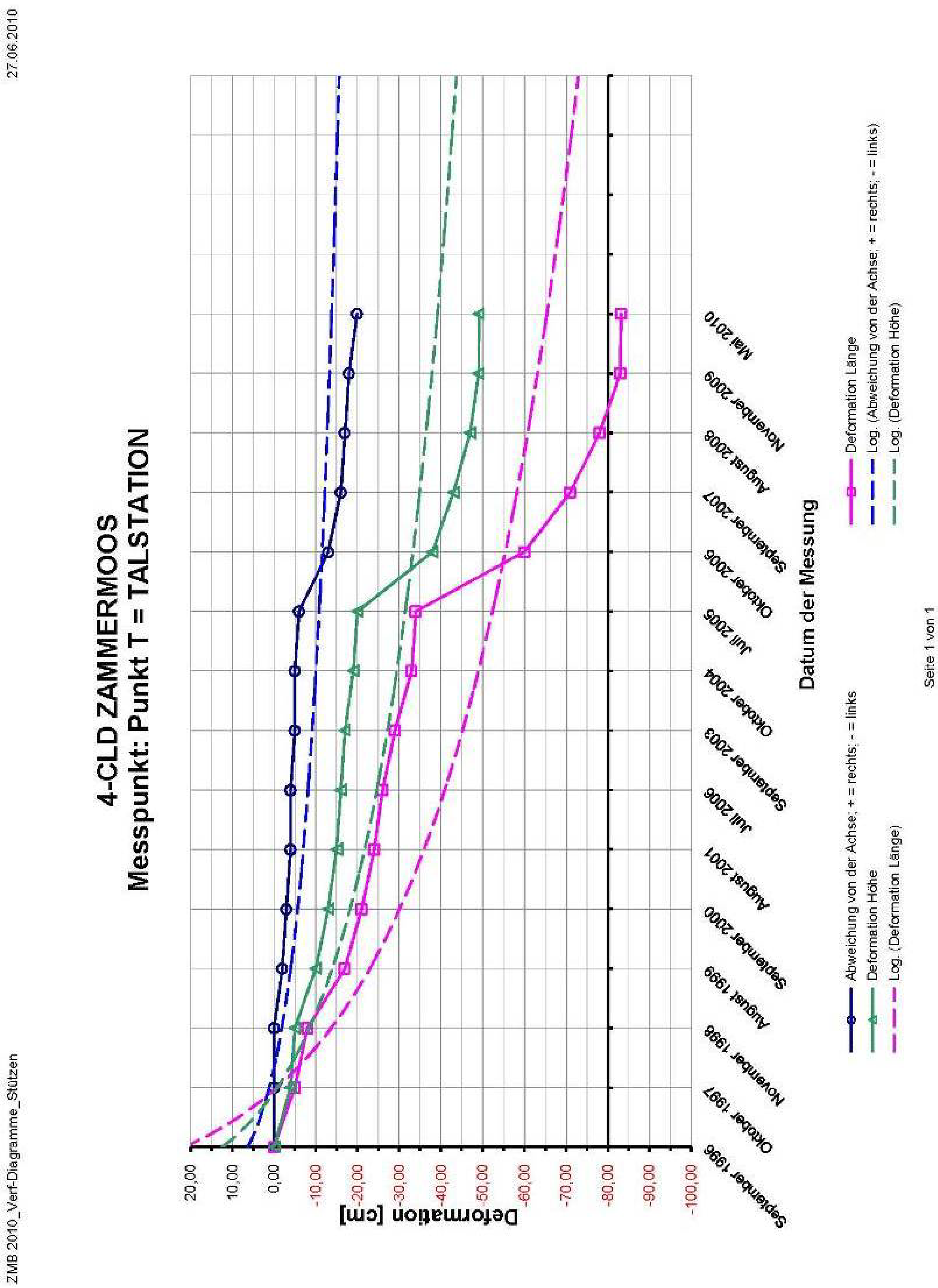
7 finished stabilization work in July 2008 – incl. wire mesh on right hand side

Survey was continued but laps between measurements were extended to 6 months. Review showed that movements decreased subsequently and reached values per year like before the flooding event in August 2005. The client, who already feared the need to build a new ropeway, is now happy with this solution, which helped to save a sum of 9 Million Euro.

The challenges of this project can be summarized:

- Technical – the ropeway structure is very sensitive and has to fulfill high safety requirements. Therefore the solution has to provide a firm supporting structure, which could be reached by the chosen A-shape micropile system.
- Logistic – site was inaccessible to heavy drilling equipment, therefore the advantages of flexible, lightweight, self-moving drilling equipment came through.
- Time – building time was restricted to a period of 4 months due to snow. Beginning was not possible before end of June due to melting snow and saturated soil. In autumn by the end of October site had to be closed due to snowfall and low temperatures. Drilling of micropiles in varying ground such as moraine as overlying soil and rock using uniform equipment was competitive. The use of hollow bar micropiles even cut down drilling time to 60% of estimated time with casing for GEWI-type micropiles.

Table 8 shows the positive effect of stabilization works on decrease of movements of station building and slope after finalizing works in summer 2008.



8 decrease of creeping velocity to a value < before flooding in 2005

Case 2 – Slope stabilization in India

9 site view East-West-Gas-Pipeline

Another interesting project began in June 2008, when after the beginning of the monsoon rain season the East-West gas pipeline in India in the state of Maharashtra was exposed due to slipping of backfill and ´loos of support 9 months before commercial operation should start.

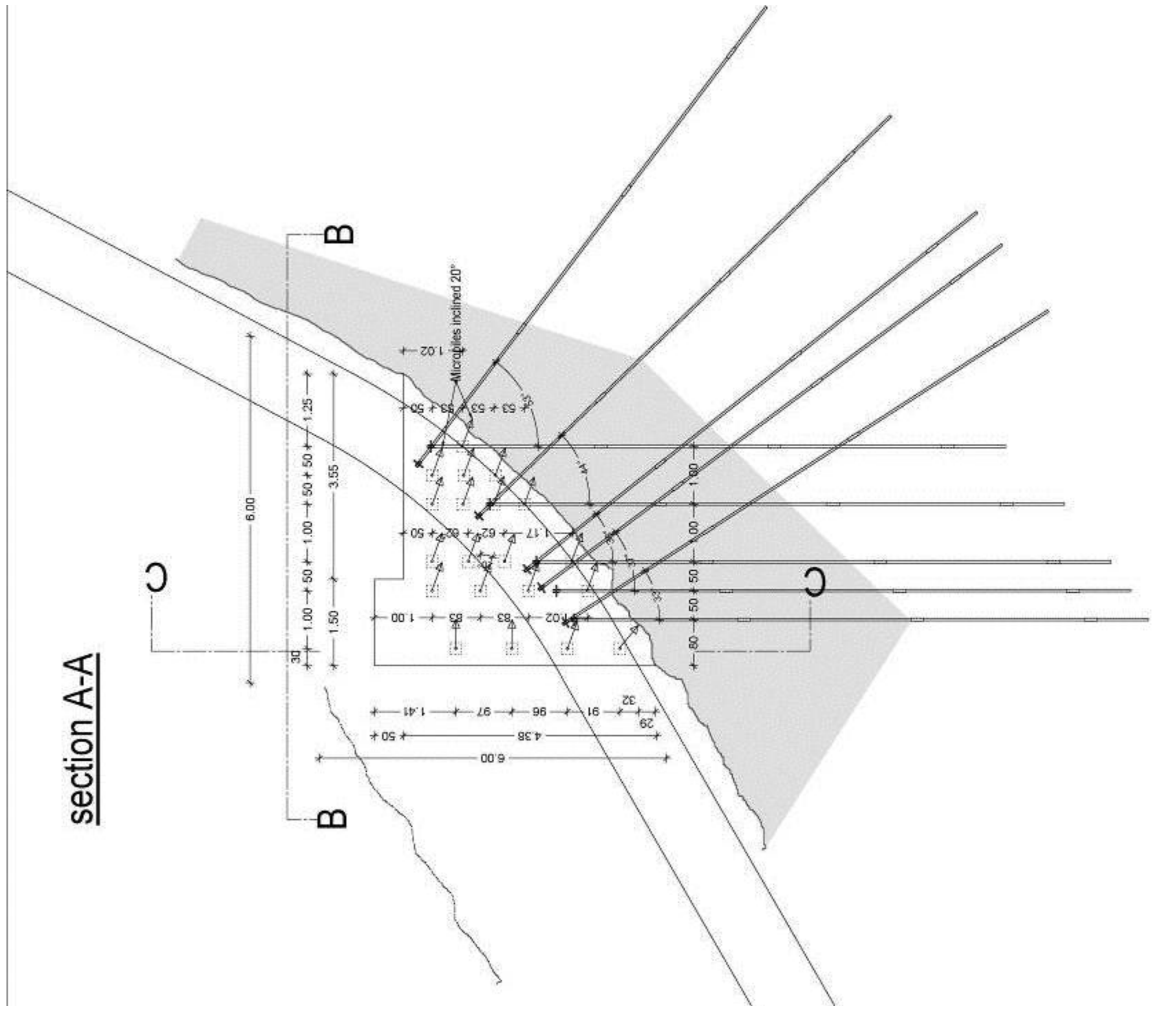
10 exposed pipeline at slope 1

The pipeline crossed the Western Ghats with two steep escarpments each 300 m in length at a height of 300 to 350 m showing an average inclination of 45° up to 70° in the middle of slope 1. At my first visit in middle of July during monsoon rain Reliance Infrastructure managers called for a solution, which should be finished by the end of March 2009 as planned for commencement of commercial operation by April 2009.

Rainwater gathering in the trench of the pipeline caused slipping of backfill and exposed the pipe over nearly the whole two slopes. In the middle of slope 1 – the upper slope – a 45 m high part at an inclination of 70° - had to be refurbished and covered to protect the pipe from rockfall impact. On an overall length of nearly 700 m backfill had to be secured, erosion protection installed, rockfall prevention measures taken and slopes stabilized. Time for execution was restricted to dry season starting by end of October. It took nearly 8 weeks to get the clients decision for commencing the design of the stabilization works. Until handover of a site survey, another 6 weeks passed before design could start.
Due to inaccessibility of the two slopes by road transport – all material and building machinery had to be delivered by two heavy duty cable-cranes installed. As road transport from Mumbai took another 1,5 days – a solution using micropiles, soil nails, heavy duty wire mesh, gabions and geotextiles was designed to reduce

transportation cost and time. Most of the equipment for drilling micropiles had to be imported to India – walking excavator with light weight drilling equipment were shipped from Europe (sea and air transport). Injection pumps and micropiles hollow bars type MAI IBO R32S, IBO R38N as well as GEWI rock bolts were provided by Atlas Copco India, while geogrid, gabions, heavy duty mesh were produced in India according to design requirements according to European and ISO standards.
The solution presented and commissioned by end of September included 1100 m of hollow bar type MAI R38N micropiles, more than 5000 m of soil nails hollow bar type MAI R32S and 450 gabion casings 200*100*100 cm and about 8000 m² of heavy duty wire mesh 50*50*4,6 mm plus the same amount of coir mats to stabilize the slopes.

In the middle of slope 1 the pipe was totally exposed on a length of about 50 m and therefore rockfall could damage the pipe. In order to protect the pipe from rockfall impact a cover consisting of anchored gabions was put on a foundation with micropiles drilled into the surrounding weak and weathered rock. In addition rock surface was secured by heavy duty wire mesh anchored with rock bolts.
The foundation block of the gabion wall was constructed on a micropile grille consisting of more than 90 hollow bar MAI IBO R38 micropiles.
The micropiles took the weight of the gabion wall to keep the pipe free from weight of the proposed gabion wall.



11 section of gabion wall foundation with micropiles MAI R38N

After finishing drilling the micropiles the foundation block was poured and construction of the gabion wall could be started. Gabions, each weighing more than 5 tons, were filled with stones at the bottom of the slope and brought to the site with help of the cable-crane.

11 stone filled gabions

All drilling work was done from 2 walking excavators, each working on one of the two slopes.

While slope 1 showed greater damage caused by water the whole length slope 2 damages were less severe and could be repaired by reinforcement.
In slope 2 the existing 3 walls built from bags filled with soil had to be secured to avoid removing all soil and rebuilding the walls. This would have caused a big time problem. Therefore it was decided to support these walls with micropiles and secure them by anchored heavy duty wire mesh.

12 drilling from walking dragline slope 2

A major problem was lack of specialized staff such as walking excavator drivers, drilling and injection staff, but also construction supervision staff. These positions were recruited in Europe, all other personnel came from India.

Another problem occurred doing the injection work. As due to high temperatures and poor cement quality injection grout set quickly and caused many problems while injection work was going on.

Stabilization works started by end of November 2008 and were finished by end of February and handed over to the client in March 2009. Despite severe conditions – temperatures during the day raised to nearly 40° C – lack of skilled staff (the number of workers was not the problem) difficulties in material support due to bad roads (the last 40 km from asphalt road to site took about 1 day for a lorry) work could be finished in time. The chosen solution proved to be stable and resistant to weather impact – heavy monsoon rain and high temperatures.

Picture will be added

13 finished slope 1 stabilization in March 2009

Conclusion

These two cases are successful examples of site use of micropiles under severe conditions, access, weather and temperatures and execution period. The advantages of micropiles are flexibility, high capacity and easy handling on site as well as commercial benefits.

References

ÖNORM EN 14199:2005 Pfähle mit kleinem Durchmesser
DIN EN 14199
DYWIDAG Geotechnische Systeme GEWIplus, GEWI Mikropfähle
DSI Ltd. – MAI hollow bar micropiles
ISCHEBECK GmbH. – Geotechnical Solutions TITAN micropiles

Brandner, A. *Einsatzmöglichkeiten von Mikropfählen und Nägeln bei Projekten im Gebirge,* Technische Akademie Esslingen, Jan. 2010